

- Cold-start fuel injector
- Special throttle body
- High-pressure electric fuel pump
- Fuel pressure regulator
- Different cylinder head gaskets used with MPFI engines
- Pistons used with MPFI engines 0.020in taller
- Larger crankshaft main bearing journals introduced mid-year
- One-piece rear main seal (10mm wide) introduced mid-year
- O-ring used to seal main oil passage between oil pump and block
- Lower friction oil control rings
- Distributor downsized
- Intake plenum lower on J-cars to clear hood
- Serpentine accessory drive belt on some models

1987

- Generation II engine introduced in front-wheel-drive vehicles
 - Cylinder heads redesigned and cast in aluminum
 - Cylinder heads require dished pistons and thicker head gaskets with unique cooling holes
 - Cast-aluminum rocker arm covers
 - Splayed intake and exhaust valves
 - Guide-mounted seals used on both intake and exhaust valve guides
 - Valve stem seal, oil shedder, and shield discontinued
 - Valve lash adjustment procedure changed
 - Intake plenum reshaped for efficiency
 - Aluminum front cover and water pump housing
 - Direct Ignition System (DIS) replaces distributor (front-wheel-drive vehicles only), fires two spark plugs simultaneously
 - Oil pump driven by oil pump drive
 - Internally balanced crankshaft incorporates "reluctor" for DIS operation; ignition timing nonadjustable
 - Compression ratio increased to 8.9:1
 - Lower friction piston compression rings
- Model 700 TBI system introduced
- Serpentine accessory drive belt
- Internally balanced crankshaft used in engines fitted to rear-wheel-drive vehicles only
 - Cast with DIS reluctor, but DIS ignition not used
- One-piece oil pan gasket

1988

- Lathe-turned pistons
- Piston weight reduced from 600gm to 540gm, and then finally to 510gm
- Internally balanced crankshafts (rear-wheel-drive vehicles only)
- Multec fuel injectors replace earlier pintle-style injectors
- Speed density engine control system replaces mass air flow (MAF) sensor in J-cars

1990

- Displacement increased from 2.8-liter to 3.1-liter
- Stroke increased 8mm
- Uses dished pistons
 - 4mm shorter than 1989 model engines
 - Features low-tension piston rings
- Single-size pistons, main bearings, and rod bearings, eliminating need for different sizes of parts during service
- Fuel pump eccentric on camshaft eliminated
- Aluminum heads used on some models

1993

- 3.4-liter version introduced in Camaro and Firebird
- Bore increased 3.03mm
- SFI system introduced
- DIS enhanced; uses additional sensor at front of block
- Cylinder block upgraded to handle additional displacement

in front-wheel-drive vehicles and those used in rear-wheel-drive lies in how each is mounted. However, the cooling systems also differ. Since the end of the engine that normally drove the cooling fan had to be positioned to the side on front-wheel-drive vehicles, electric cooling fan(s) were required. To further accommodate this change in engine position, the thermostat housing was repositioned to the fly-wheel end of the engine.

Differences among Front-Wheel-Drive Engines

The main difference in front-wheel-drive vehicles is the location of their water pumps. In vehicles with large engine compartments, the water pump lies directly above the crankshaft. On Cavalier- and Beretta-sized cars, with their smaller engine compartments, the water pump was moved up and to the side of its "normal" location. These cars also use a lower-profile intake plenum, and their engines are inclined at a steeper angle to provide more hood clearance.

Should You Rebuild?

To rebuild or not to rebuild. That is the question. Does the engine before you really require a rebuild or just a new power steering pump. What, you might ask, does a power steering pump have to do with an engine rebuild? In a word, nothing. And that's precisely the point. A dying power steering pump can produce a knocking noise that's much like that made by a spun main bearing. If you pull the engine without first checking for other culprits (like that steering pump) you may find yourself wasting much time and money. Determine if the engine is the cause of a noise before you even *consider* rebuilding it. The same goes for poor performance and oil consumption, because several things other than the engine can cause these problems as well. Always remember to look beyond the engine before starting that "essential" engine rebuild.

How Maintenance Influences Engine Longevity

Just because an engine has traveled many miles doesn't mean it needs to be rebuilt. Regular maintenance has a major impact on engine life. If the engine oil and oil filter were changed every 3,000 miles and the air filter was changed every 10,000 miles, chances are good that the engine will run well over 100,000 miles before it requires any major service. GM's 60deg V-6 engine is so well-built that 200,000 miles before a rebuild is not out of the question. The type of driving the engine was subjected to also has a bearing on its life. Freeway driving is easier on the engine than stop-and-go operation or racing.

Other than an outright failure, oil consumption, noises, and poor performance are the three major factors that will dictate whether an engine should be rebuilt.

Generally speaking, if the engine burns less than 1qt of oil every 2,500 miles, exhibits no unusual noises, and performs well, it probably doesn't need to be rebuilt. On the other hand, if the engine swills oil like a drunken sailor or sounds like a

mariachi band, roll up your sleeves, get out your tools, and prepare to pump life into the undead.

The following sections will discuss the problems of oil consumption, abnormal noises, and abnormal and poor performance, and show you how to check for each.

Oil Consumption

Excessive oil consumption is a good reason to rebuild an engine. But how much is excessive? Some oil consumption is normal for all engines. According to GM, an engine doesn't have an oil consumption problem until it's burning 1qt of oil every 750 miles! Yet it's not unusual for a high-mileage GM 60deg V-6 in decent condition to use only 1qt of oil every 2,500 miles. Even if your engine is using more oil than this, it still may not require a rebuild. You must first determine if it's burning the oil, or just leaking it, before you think about rebuilding.

Use the Proper Oil

First thing to check: Are you using the correct weight oil? Use of the proper weight engine oil has a direct impact on oil consumption. Engine oil that's too light will more readily find its way past gaskets and seals. This is especially true of synthetic oils. An oil that's too light works its way past the piston rings more readily, and is then burned in the combustion chamber.

Using a heavier weight oil to control oil consumption, however, is not necessarily the answer. An oil that's too heavy, can't get to all the internal engine components fast enough during engine start-up, allowing them to rub against each other without the benefit of lubrication. This increases wear during engine start-up—a time when engine wear is at its greatest.

Beyond an oil's weight, also consider its rating. Only use oils rated "SH," "SH/CC," or "SH/CD" by the American Petroleum Institute. A high-quality, 5W30 SH-rated engine

oil will provide excellent engine protection under most conditions.

Internal and External Oil Leaks

Oil leaks can be internal or external. Internal leaks are typically caused by worn piston rings, worn valve stem seals, and the like, whereas external leaks are usually the result of cracked, mispositioned, or hardened gaskets or seals. An external leak of only a few drops per mile can add up to a loss of a quart of oil for every few hundred miles driven. You need to find and eliminate all external oil leaks before condemning the engine to a rebuild.

Finding external leaks is much easier if you first degrease the engine. Foamy Engine Brite by Gunk seems to work best, but Simple Green by Sunshine Makers, Inc., works fairly well and is kinder to the environment. Whichever cleaning product you choose, it's best to scrape off any heavy deposits before applying the cleaner.

The engine can be cold or warm during the cleaning operation, depending on the cleaner you're using, but never hot. If you spray cold water on a hot engine, the resulting thermal shock could crack exhaust manifolds, cylinder heads, or even the block. Remember to remove the air cleaner and cover the carburetor and distributor with plastic freezer bags to avoid spraying water directly on them. Plug any hoses that were attached to the air cleaner so water doesn't end up where it shouldn't, and check that the dipstick is in place and fully seated.

After you've applied the cleaner, use a stiff-bristled brush to scrub any particularly dirty areas. Then rinse the engine with a strong stream of water. Repeat this process twice to ensure the engine's cleanliness. Remove any plastic bags, reinstall the air cleaner, and then run the engine to dry it off. After the engine is clean and dry, you have the choice of taking the low-, medium-, or high-tech route to leak detection.

The Low-Tech Route

Spray the entire engine with aerosol foot powder and run it at 2000rpm for 2-3min while you look for the leak. Any oil leakage will show up as brown or black spots in the white powder. Pay extra attention to the areas where the manifold seals to the cylinder heads and block, as GM 60deg V-6 engines are known for leaking oil there. Don't be fooled by a leaking distributor (or oil pump drive) base gasket, as this gasket has been known to leak as well. Other possible areas of external oil leakage include the valve cover gaskets, oil pan drain plug, oil filter seal, oil pan gasket, front crankshaft oil seal, and rear main seal on the crankshaft.

If you don't find the leak after running the engine, leave a cardboard sheet under the engine overnight. In the morning, note where the drops on the cardboard are, and then carefully check those engine area(s) immediately above the spots. Unfortunately, this technique doesn't work as well on engines that drive their own cooling fans, because the air from the fan tends to push the oil toward the rear of the engine away from the actual leak source.

The Medium-Tech Route

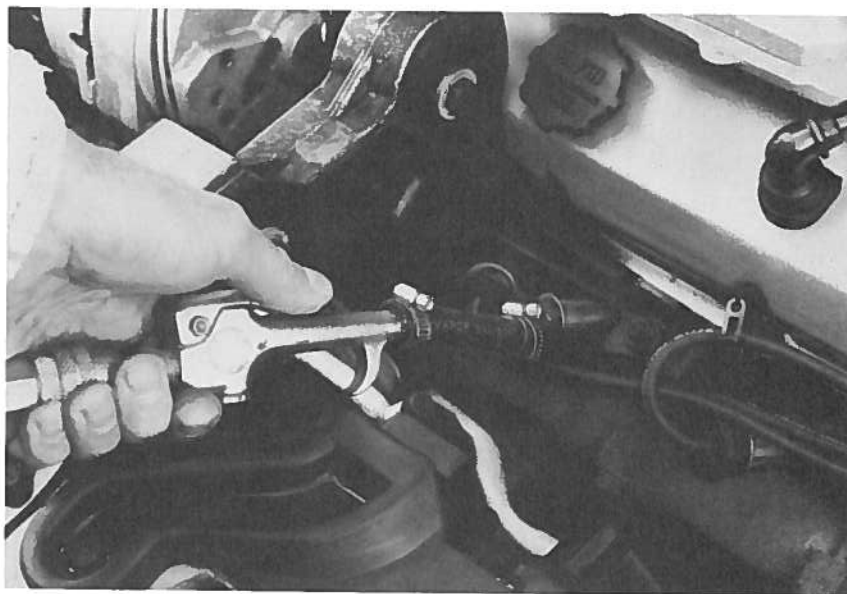
The medium-tech approach entails connecting an air compressor hose to the end of the empty dipstick tube. After applying a maximum of 4psi (no higher, or you'll blow engine seals), spray the engine with a solution of one part liquid dishwashing detergent combined with four parts water. If the seals or gaskets won't hold against the air pressure, you'll see bubbles. For areas that aren't readily visible, use a length of heater hose to listen for air escaping.

The High-Tech Route

If you still haven't found a leak, it's time to try the high-tech route. This requires two items: a bottle of oil leak detector and a high-intensity black light. You can pick up the leak detector (typically 4oz) at many auto parts stores. The same store may also rent black lights. If not, try your local tool rental shop.

To find any leaks, add the detector to the engine oil. Then run the engine while looking at it closely under the black light; any oil leakage will glow green or yellow. If you can't find a leak now, there probably isn't one.

Other than leakage, the most



You can use air pressure and a soap solution to find the source of an engine leak. However, never let air pressure

exceed 4psi, as you'll blow all the seals in the engine, and then you will definitely have to rebuild it!

common causes for oil consumption include sustained high-speed driving, failing to upshift at a reasonable engine speed, using an oil that's too light in viscosity, and too many short trips. Short trips can cause oil consumption because the engine doesn't warm up fully. This eventually causes the piston rings to stick in their grooves, impairing their ability to keep oil out of the combustion chamber and leading to oil burning.

Where There's Smoke . . .

You say your engine is too young to smoke? Maybe so, but if your engine has taken up this unsavory habit, use the color of the smoke to help you determine the source of your powerplant woes.

Black smoke funnelling out the tailpipe is unburnt gasoline. This can be caused by several things, the most common being a dirty air filter, plugged fuel injectors, a choke that's stuck in the closed position, or a carburetor float level that's too high.

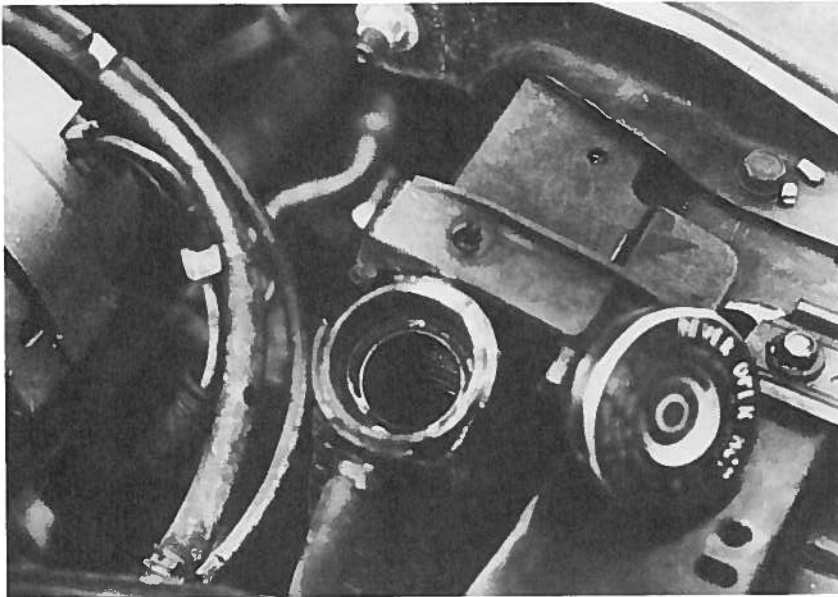
White smoke after a cold engine has been started is caused by water vapor in the engine and exhaust system being expelled. This is normal and will subside once the engine is warmed-up sufficiently. White smoke after the engine is warmed up, however, may indicate that the engine is burning transmission fluid or that a head gasket is blown.

If your car's automatic transmission uses a vacuum modulator and the diaphragm in the modulator is cracked, engine vacuum will pull transmission fluid through the cracked diaphragm into the combustion chambers, where it's burned. Since no engine oil is being burned, the oil level won't drop, but the transmission fluid level will. If the tranny fluid level drops more than one pint or so, the transmission will begin to slip. This would cause what would seem to be an engine power loss, but in reality is transmission slip.

To check for this problem, remove the vacuum line from the vacuum modulator and insert a clean pipe cleaner into the modulator. Withdraw the pipe cleaner; if it has oil on it, discard the modulator and install a new one. Add enough transmission fluid to replace what has been burned.

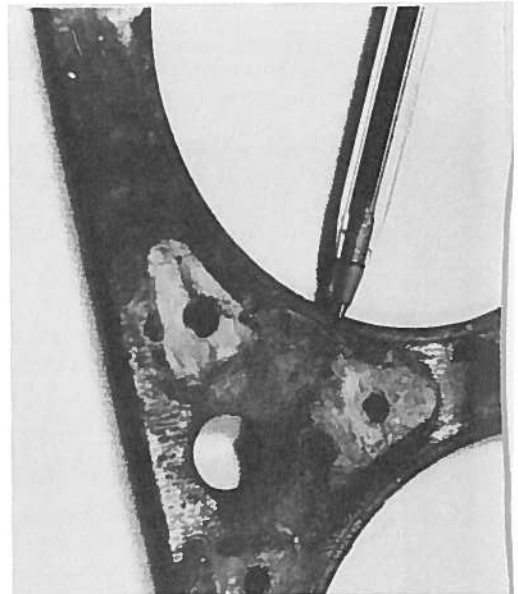
White smoke billowing out the exhaust when the engine is warm might also indicate a blown head gasket or a cracked block or head(s). This type of problem is usually coupled with coolant seeping out where the exhaust manifold meets the exhaust pipe and the sweet smell of burning coolant.

Another clue that a head gasket has failed or that the block or heads have cracked is engine oil with a milky, coffee-colored appearance.



One way of checking for a blown head gasket is to watch the coolant in the radiator as the engine heats up to operating temperature. Bubbles in the coolant can indicate a bad head gasket. If white

smoke comes out of the exhaust after the engine has warmed up, check the transmission fluid level. If it's where it should be, the head gasket is probably blown.



If a head gasket has failed, allowing coolant to mix with the oil, check both head gaskets as you disassemble the engine. Eroded areas on the gasket usually indicate where the problem lies.

This is caused by a failure of the head gasket material between a lubrication passage and a coolant passage, which allows oil and coolant to mix in the engine. You can check for this by removing the oil dipstick and inspecting the oil on its end. If the oil has the dreaded color of coffee with milk and feels creamy, you can plan on replacing most of the engine's components. Coolant-diluted oil offers very little in the way of lubrication.

Coolant that has mixed with the engine oil doesn't always show up on the dipstick, however. In some cases, the oil will mix with the coolant but go no further than the cooling system. Check the coolant color and condition in the coolant recovery bottle or radiator to see if this is the case.

Another clue that a head gasket is blown is that bubbles will appear in the radiator when the engine is running. Check for this by removing the radiator cap when the engine is cool and then watching the coolant in the radiator until the engine is up to normal operating temperature. It's also common for the coolant level in the radiator to drop when the head gasket is blown, however no coolant leak will be readily apparent.

If you suspect a head gasket has failed, look for erosion between its lubrication and cooling passages when

you remove the cylinder heads. Eroded areas on the gasket indicate that the head bolts weren't tight (or that they cracked), that the head and/or block is low in that area, or that the head gasket was faulty.

Another way to test for a head gasket leak is with a combustion leak tester. Although this tester can't detect some leak types, like coolant leaking to the outside of the head, it is effective at detecting carbon monoxide (CO)—a byproduct of the combustion process—in the cooling system. The only way CO can enter the coolant is if the head gasket is leaking.

To use this detector, you need to lower the coolant level in the radiator about 2 in to allow any gases in the cooling system to rise to the top of the radiator. Next, pour a small amount of the CO-sensing chemical that comes with the kit into the detector and connect the detector to the radiator in place of the radiator cap. Start the engine and let it idle until it reaches normal operating temperature. If any carbon monoxide exists, the chemical will turn from blue to yellow.

If the head gasket is leaking, you will usually have to machine the cylinder head and/or cylinder block. And if a head gasket has allowed coolant to mix with the oil, you will

probably have to replace or recondition all of the internal engine components.

Internal Oil Leakage

If your engine has been properly maintained and treated well and doesn't have any of the aforementioned problems, but is still an oil consumer, chances are good that it has an internal oil leak. Deteriorated valve stem seals and excessively worn valve guides seem to be the most frequent cause of internal oil consumption. These two conditions, alone or jointly, allow oil to be pulled into the combustion chambers, via the valve guides, where it's burned.

Internal oil consumption can be checked by starting the engine when it's cold. If blue smoke comes out the exhaust just as the engine is started, the valve stem seals are probably faulty or the valve guides may be worn. Valve stem seal replacement can be done without removing the engine (the procedure is covered in Chapter 6) and sometimes is all that's needed to cure an oil consumption problem.

You can do some further checking by letting the engine reach its normal operating temperature, then quickly flooring the accelerator with the car in neutral. If blue smoke bil-

lows out the exhaust, the piston rings are probably worn. If smoking occurs when you lift your foot off the gas, the valve stem seals or valve guides need attention.

To pinpoint the problem cylinder, remove each spark plug and inspect for oil-fouling. If any are oil-fouled, pay particular attention to the piston rings, valve guides, and valve stem seals for that particular cylinder when you tear down the engine.

Other things to check for before removing the engine to repair an internal oil leak are a plugged or incorrect positive crankcase ventilation (PCV) valve, a restricted PCV valve hose, or plug-ged oil drain-back channels.

A PCV valve helps prevent oil contamination by removing residual gasoline vapor and oil fumes from the engine oil. It also helps relieve crankcase pressure by venting the vapor and fumes back into the engine where they're burned.

If the PCV valve is plugged, restricted, or of too low a capacity, crankcase pressure will build. When pressure surpasses a certain point, the piston rings can't seal as tightly as they were designed to. This allows engine oil into the combustion chambers, where it's burned. Excessive crankcase pressure can also cause oil to push past the seals, causing an external oil leak.

Checking a PCV valve by shaking it to see if it rattles only indicates a failure when the valve is plugged. The rattle test will not identify a valve that is restricted or stuck. If you have any doubts about the PCV valve, replace it. And if the oil consumption problem started when the PCV valve was changed, chances are the new PCV valve is bad and needs to be replaced with another new valve.

Also check the PCV valve hose. Its inner wall will sometimes collapse, causing excessive crankcase pressure, just as a plugged PCV valve would.

If the cylinder heads' oil drain-back channels are plugged, the oil that lubricated the valvetrain cannot drain back into the crankcase and remains on top of the heads. Since engine vacuum is prevalent around the valve guides, the oil lying atop the heads is sucked into the combustion chambers and is burned. Restricted oil drain-back channels can also cause this problem, but to a lesser degree.

Check for this problem by removing the valve covers and inspect-



A combustion leak tester will help you find a head gasket that is leaking compression. These sell for \$25 to \$40, a small investment when you consider

that they might save you the trouble of pulling the cylinder heads unnecessarily.

ing the drain-back channels. Each cast-iron head has two channels, one near the front and one near the rear. Each channel is positioned between the rocker arms, at their base. Aluminum heads use three channels

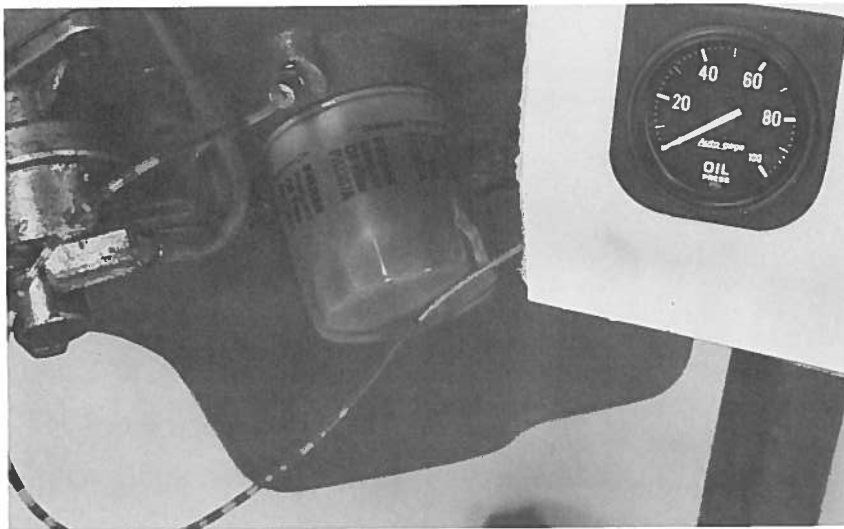
each, located near the head's center.

If the channels (or holes) are clear, you should be able to stick the blade of a medium-sized screwdriver into them. If you can't, clean them with a small screwdriver, while using



Check for a plugged PCV valve if your engine is pumping oil out the exhaust. An obstruction in the valve or the hose

leading to it can increase crankcase pressure to a point where it allows oil to be burned.



To verify an oil pressure problem, use a mechanical oil pressure gauge. Connect its supply tube to where the oil pressure switch is normally located. If

oil pressure is fine, the oil pressure switch, sending unit, or associated wiring is faulty.

a vacuum to pick up any debris so that it won't get into the engine. It's also a good idea to change the oil after briefly running the engine to allow the old oil to wash any remaining debris into the crank-case, where it will be drained.

Plugged oil drain-back channels indicate that the oil and/or oil filter weren't changed frequently enough, the wrong viscosity of oil was used, or that the oil didn't have an "SF" or better rating.

Oil Pressure Versus Engine Condition

Engine oil pressure can give you an indication of engine and oil pump wear. If the engine is in good condition, filled with the proper weight oil, and is at normal operating temperature, oil pressure should be 25–40psi at 1000rpm and 45–55psi at 2000 rpm. Minimum oil pressure is 15psi at 1000rpm and 30psi at 2000rpm. If oil pressure is somewhat less than this and drops to 15psi or less at idle, the clearances between the bearings and the crankshaft journals are excessive. Remember, you shouldn't measure oil pressure when the engine is cold because the reading will be higher than when the engine is fully warmed. This might lead you to the wrong conclusion.

If your vehicle isn't equipped with an oil pressure gauge, remove the oil pressure switch and replace it with a mechanical gauge. The oil

pressure switch on front-wheel-drive engines is located on the block, just above the oil filter. On rear-wheel-drive vehicles, it's on the oil filter adapter, behind the filter.

If your vehicle's oil pressure warning light comes on when the engine is idling, there probably is a significant internal oil leak. Keep in mind, however, that the oil pressure switch could be faulty. If the engine doesn't produce a ticking noise at idle, which would indicate an inadequate oil supply at the rocker arms, the switch is probably bad. If, however, you do hear ticking noises, the engine most likely has an internal oil leak. In this case the likely sources of the problem are the bypass valve in the oil pump sticking in the open position, worn oil pump gears and/or housing, or worn main, connecting rod, or camshaft bearings.

Abnormal Noises

Abnormal engine compartment noises can lead you to believe that something's wrong with the engine. Before you conclude that your engine needs to be rebuilt, however, bear in mind that numerous things external to the engine can cause noise. These can include the power steering pump, air conditioning compressor, alternator, air injector reactor (AIR) pump, water pump, and accessory drive belts. And that's just component-based noises; improper ignition timing and/or the use of low-octane fuel can also cause certain types of noises.

For example, overly-advanced ignition timing can cause a type of engine-based noise called detonation or spark knock. This noise can sound like a baby rattle or pans knocking together, but the cause is still the same: gasoline that is igniting before the piston is moving down in the cylinder bore. If this condition is not repaired, it can cause piston rings and/or pistons to crack. In severe cases, it can even cause head gasket failure.

Fuel that's too low in octane lacks a sufficient quantity of "anti-knock" additive and can also cause spark knock. Be sure to use the right octane fuel, but don't go overboard. If your engine requires only 89 units of octane, you're wasting your money buying gasoline rated any higher.

Fuel quality is just as important as octane rating. High-quality fuel will help minimize deposits in the inlet system and combustion chambers, which helps prevent engine-damaging spark knock and helps maintain peak engine performance over time.

Spark plugs of the correct heat range are also important. Different spark plugs are designed to operate at different temperatures—this defines their heat range. If the spark plugs in your engine are operating at too high of a temperature, the air/fuel mixture can ignite at the wrong time resulting in spark knock. To make sure your spark plugs are of the correct heat range, review the nearby "Reading Spark Plugs" sidebar.

Testing for Abnormal Engine Noises

You can check for noises in three basic ways: by removing accessory drive belts, by listening with a stethoscope, and by grounding spark plug wires.

Removing Accessory Drive Belts

Some engine noises can be isolated by removing the accessory drive belts one at a time. If the noise stops, you'll know that whatever component was driven by the belt is what needs your attention, not the engine. Limit this type of testing to 2min if the belt you're removing drives the water pump—otherwise the engine may overheat, a sure sign of which is knocking.

A glazed accessory drive belt is the usual source of squeals and squeaks. However, if the accessory components are not the cause of the noise or if all the accessories are dri-

ven by one belt, you'll want to check further by using a mechanic's stethoscope.

Using a Stethoscope

Mechanic's stethoscopes are available at many auto parts stores and can help you pinpoint the location and distinguishing features of many types of mechanical sounds that your unaided ears can't locate.

To use the stethoscope, screw its metal probe onto the diaphragm and place the ear pieces in your ears. Hold the probe against the suspected area of noise while the engine is running. The stethoscope will amplify any noise; just be sure to stay clear of rotating and hot parts.

It's a good idea to familiarize yourself with the noises normally generated by the accessories and engine before you replace a particular part. If you're not sure how a part should sound, listen to the same part—in good condition—on another car.

A screwdriver or metal rod 18in or longer is a cheap alternative to a stethoscope. Place the screwdriver's blade against the area in question and then put the handle against your ear. The downside to this method is that it may not work as well as a stethoscope, and your ear might be pounded as the screwdriver or rod moves.

A length of heater hose about 2ft long can help you locate vacuum leaks at the carburetor and inlet manifold, among other areas. Hold one end of the hose against the suspected area and the other end against your ear, and listen for a sucking sound.

If you think you've found a vacuum leak, spray the suspected area with carburetor cleaner. If a leak does exist, the engine will draw the carb cleaner in, causing it to briefly run smoother. This trick works best with carbureted vehicles; engines equipped with both Computer Command Control (C3) and fuel injection can compensate for anything short of a massive vacuum leak. You'll need to listen very closely for vacuum leaks on engines equipped with both C3 and fuel injection systems.

Grounding Spark Plug Wires

Another way to isolate the source of a particular engine-based noise is to ground the spark plug wires (one at a time) while the engine is running. To do this, you'll need an ignition system grounding kit. This

kit consists of coil-spring-like jumpers and is available at many auto parts stores.

Caution: Don't try this test by merely pulling the plug wires off while the engine is running. If you do, you'll probably destroy the ignition module and you may be electrocuted.

To install the jumpers, remove the spark plug wires one at a time. Rotate the spark plug boot about one-half turn while pulling it off the plug to avoid destroying the plug wire. Slide a jumper over the tip of the plug, then reconnect the plug wire. Do this for all cylinders. To ensure the accuracy of your testing, keep the jumpers away from any potential grounding sources.

Now connect a 6ft long piece of 12-gauge (minimum) wire to the battery's negative terminal. This will provide a good ground path when grounding out the spark plug wires. To ground out any plug wire when the engine is running, hold the end of the grounding wire with insulated pliers and touch it to the jumper for that cylinder. If the noise stops or changes tone when a plug wire is grounded, chances are good that something is wrong in that cylinder. The noise should reappear when you disconnect the ground wire.

Caution: Be careful when grounding spark plug wires with the engine running because you can get a strong shock from the ignition system—perhaps even a lethal one if your engine is equipped with a digital ignition system.

This system can be identified by following one of the plug wires from the spark plug to its other end. If the end of the spark plug wire is attached to an ignition coil the size of a small orange, and just one other spark plug wire is attached to it, the ignition system is of the digital type. GM 60deg V-6 engines fitted with DIS have three ignition coils with two spark plug wires running to each coil. In many cases, these coils are mounted on the radiator side of the engine, on the block, below the exhaust manifold.

Always use insulated pliers to hold the spark plug and grounding wires when the engine is running. Using one hand while not touching the vehicle with any other part of your body also reduces your chances of injury by not providing a ground path

for electricity.

Locating Abnormal Engine Noises

It's easier to diagnose engine noises if you can characterize the sounds and identify when they occur. Noises generally fall into the categories of knocking, rapping, ticking, or rumbling. Does the noise occur when the engine is cold or hot? Does it

Reading Spark Plugs

The condition of the business end of an engine's spark plugs can tell you a lot about the condition of the engine. And it's the closest you'll get to looking at the combustion chambers without removing the cylinder heads.

If the engine isn't burning a perceptible amount of oil and the air/fuel mixture from the carburetor or fuel injection system is near the optimum 14.7:1, the spark plug's porcelain insulator will be a tannish-brown to reddish-tan in color. If the plugs are this color, the engine's in good condition and the heat range of the spark plugs is well-suited to the engine and driving conditions.

A spark plug that's black and oily indicates an oil consumption problem in that particular cylinder. This can be caused by faulty valve stem seals or worn valve guides, piston rings, and/or cylinder bore.

A spark plug that's a powdery matte-black could be the result of extended idling. It could also indicate an overly rich air/fuel mixture, a plugged air filter, a bad spark plug wire, a bad spark plug, or poor ignition system output.

A spark plug that has severely overheated will have a burned or blistered insulator tip and a badly eroded electrode. If a spark plug looks like this, it may be too hot for the particular driving conditions encountered, such as high-speed operation. This problem can also be caused by using fuel that doesn't have enough octane, incorrect ignition timing, an air/fuel mixture that's too lean, or a faulty cooling system.

Electrode damage is indicated by a side wire or center electrode that's burned away. This damage indicates that something is seriously wrong and needs to be corrected immediately before valve or piston damage occurs. Electrode damage can be caused by a faulty cooling system, using fuel with too low an octane rating, incorrect ignition timing, an air/fuel mixture that's too lean, or spark plugs that are much too hot for the driving conditions encountered.

get louder as engine rpm increases, or does it just happen more often? Does the noise get louder when the engine is under a load? Answers to these questions will put you well on your way to finding the cause of the noise.

Knocking and Rapping Noises

A *torque converter knock* will produce several quick raps when accelerating an unloaded engine (automatic transmission in Park or Neutral). This knock can be heard at the engine's rear and sounds like a connecting rod bearing knock. A torque converter knock is much easier to fix, though, so always check for it before you attempt to repair the engine for a connecting rod bearing knock. Depending upon engine idle smoothness, this type of noise may appear at idle when the transmission is in Reverse or any of the forward gears. If you suspect a torque converter knock, check for loose torque converter-to-flexplate attaching bolts and for cracks in the flexplate.

Power steering pumps can produce a knock that sounds like a connecting rod bearing knock. However, a power steering pump knock is heard at the power steering pump and varies with the speed of the pump pulley.

Piston pin knocks are located high on the block and are louder when the engine is cold. They are the result of the piston pin bore in the piston being worn into an oval shape parallel to the cylinder. As the piston reaches the top of its stroke, the upward inertia causes the bottom of the piston pin bore to hit the piston pin. As the piston moves down the cylinder, the piston pin stays tightly against the piston pin bore, but as soon as the piston reaches the bottom of its stroke, the top of the piston pin bore hits the piston pin. As a result, piston pin knocks produce a double rapping sound. The knock will disappear when the spark plug wire from the affected cylinder is grounded.

Piston knock (or piston slap) increases in frequency as engine rpm increases and is located high and to one side of the block. A piston knock sounds like a piston pin knock, but produces only one knock with every crankshaft revolution, whereas a piston pin knock produces a knock twice every crankshaft revolution. A piston knock is due to excessive clearance between

the piston skirt and cylinder wall. And since operating clearances are at their greatest when the engine is cold, a piston knock is loudest then. Piston pin knock may disappear when the spark plug wire from the affected cylinder is removed.

Connecting rod bearing knocks can be heard near the bottom of the engine block. This type of problem produces a medium to heavy knocking sound, which becomes more frequent as engine rpm rises. Although rod bearing knocks can sound like main bearing knocks, they're louder when the engine is unloaded. Also, rod bearing knocks usually disappear when the spark plug wire from the affected cylinder is grounded. Connecting rod bearing knocks are usually caused by excessive clearance between the rod bearing and crankshaft journal. This excessive clearance allows the bearing to hit against the crankshaft, producing a knocking noise. Connecting rod bearing knocks can also be caused by loose, misassembled, or mismatched connecting rod bearing caps.

Main bearing knocks are similar to connecting rod bearing knocks in that they are relative to engine speed and are heard low in the block. However, main bearing knocks are heavy and usually louder when the engine is under a load, and they change tone or disappear completely when the engine is unloaded, as when the transmission is in neutral.

Main bearing knocks are usually the result of too much clearance between the main bearings and the crankshaft. This type of knock also occurs when the main bearing caps are loose, in the wrong position on the block, or are installed backwards.

The front main bearing is the most likely place to find a main bearing knock because all the engine-driven accessories are driven off the front of the crankshaft. Since the air conditioning compressor exerts the greatest load on the front main bearing, turn on the air conditioning system when trying to locate a front main bearing knock.

Ticking Noises

Ticking noises usually indicate a problem with the accessory drive belts, exhaust system, mechanical fuel pump, valvetrain, or lubrication system.

Accessory drive belts can produce a ticking sound if the outer portion of the belt begins to peel away and hits another object while the belt is rotating.

Exhaust systems can produce a ticking noise if the exhaust manifold is leaking. An exhaust manifold usually leaks because its retaining bolts have come loose or its gaskets have blown. This allows exhaust gases to vent before they pass through the exhaust system. Cracked AIR tubes on the exhaust manifolds may cause a ticking noise as well.

Spark plugs that are loose can cause a ticking noise as the compressed air in the cylinder rushes past them.

Mechanical fuel pumps can produce a ticking noise that sounds like a faulty valve lifter. It is heard at the fuel pump housing and is not relative to engine speed. To determine if the fuel pump is the noise source, loosen the pump's retaining bolts, then run the engine. If the fuel pump is the source of the noise, the noise will change tone.

The valvetrain (lifters, pushrods, rocker arms, and rocker balls) is the first place you'll hear oil-related ticking sounds. That's because it's the point farthest from the oil pump and, consequently, the last area that's lubricated. Ticking noises in the valvetrain can be caused by an engine oil level that's too low or too high or by too thin an oil.

If the engine oil level is too low, there won't be enough oil to lubricate the valvetrain. This increases the operating clearance between valvetrain components, allowing them to slam against each other and produce a ticking sound.

If the engine oil level is too high, the oil closest to the crankshaft will be whipped into a foam by the spinning crankshaft. This foamy oil is then fed by the oil pump to the valvetrain, and since it is mostly air, it can't lubricate properly or fill the spaces between components as a solid film of oil can. Again, the result is greater operating clearances between the valvetrain components and a ticking noise.

Bad valvetrain components can also cause ticking sounds. For example, valve springs that are out-of-square or are broken will make a ticking sound heard at or near the valve cover. It is not load-sensitive.

Valve guides that are excessively worn will produce a ticking sound because the valve stems are rocking in them.

Valve lifters that are sticking, faulty, or damaged will make a ticking sound as well. If the sound lasts only for a second or two after engine start-up, the problem is due to oil bleeding out of the lifter(s) and there is little need for concern. Noise that appears to be from the valve lifter or valve spring area, however, could also be due to an engine oil level that's too low or too high.

Engine oil that's too thin can also cause valvetrain noises because it doesn't adequately fill the clearances between parts.

Rumbling Noises

Dying water pumps produce a low, rumbling sound. If the water pump is engine-driven, the noise may become quieter when the water pump drive belt is loosened.

Popping Noises

A popping noise that comes from the carburetor or throttle body and is more noticeable under acceleration can mean that the ignition timing is incorrect or that the camshaft lobes are excessively worn. If the lobes are worn, engine performance will be substandard. Instructions on how to check the camshaft lobe lift are given later in this chapter.

Poor Performance

Poor performance can manifest itself in several ways. Some of these factors really aren't related to the engine but can cut performance substantially. This can include such things as a slipping clutch or transmission, dragging brakes, under-inflated tires, and poor fuel quality. Check for these problems first. Then check for engine-related problems, such as retarded ignition timing; a cooling system thermostat that's stuck closed; an externally or internally blocked radiator; a collapsed radiator hose; a plugged air filter; fouled spark plugs; an incorrectly adjusted fuel system; a failed ignition system; too great a valve lash; an incorrectly timed camshaft; worn camshaft lobes; leaking, stuck, or broken inlet and/or exhaust valves; worn piston rings and/or cylinders; and a blown cylinder head gasket. Of these, only the last six require engine repair.

Valve lash that's too great reduces valve lift and, in turn, engine power. Repair of this problem requires removing the rocker arm cover(s) and adjusting the rocker arm to pushrod clearance. Cam-shaft timing affects engine performance as well. If the camshaft is not properly timed to the crankshaft, the valves will be open at the wrong time and will affect power output. For more information, see Chapter 6.

Power Balance Test

A power balance test compares each cylinder's power output. If one cylinder has less power than the others, engine rpm will hardly drop when the spark plug wire for that particular cylinder is grounded. This indicates a mechanical problem for that cylinder.

To perform a power balance test, connect a tachometer to the tach lead at the distributor. Idle the engine at 800–900rpm and set the tachometer to the 0–1000rpm scale. If your vehicle is equipped with an automatic transmission and you can't get it to idle below 1000rpm, put it in Drive, put the parking brake on, and have someone apply the brakes. You need to have the engine below 1000rpm so that you can use the more sensitive 0–1000rpm scale on the tachometer.

To check the power output of each cylinder, ground each spark plug wire following the procedure outlined earlier in this chapter. As each cylinder

is grounded out, there should be an approximate 25rpm drop. If the readings vary by more than about 50rpm, suspect a problem. Just remember that the cylinders with the least rpm drop are bad.

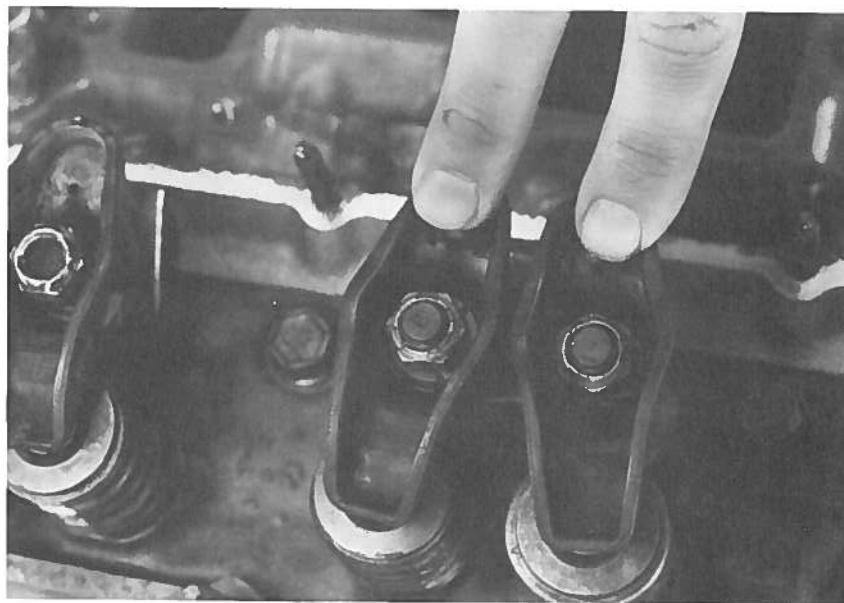
Camshaft Lobe Checking

The camshaft lobes should be checked when you notice that the engine lacks power or runs roughly even though the ignition timing is set correctly, there are no vacuum leaks, and the fuel system is working properly.

One of the major determinants of engine power is camshaft lobe height. Generally speaking, the higher the camshaft lobes, the more power an engine will make. On the other hand, if the camshaft lobes are worn, power will be reduced. Camshaft lobe testing checks the height (also known as lift) of each camshaft lobe.

One clue that a camshaft lobe is worn is that the rocker arm that is actuated by that lobe will be excessively loose when compared to the other rocker arms. To do a thorough job, measure the height of all the lobes, not just those that are loose. This can be done with the camshaft in or out of the engine.

To check camshaft lobe lift with the cam in the engine, place a finger on the pushrod end of the rocker arm whose cam lobe you want to check. Place a breaker bar with socket on the



The pushrod end of the rocker arm (indicated here) should be at its lowest

position to begin measuring camshaft lobe lift.



Place the end of the dial indicator into the lube hole on the end of the pushrod. Preload the indicator about 0.100in to ensure an accurate measurement. When the indicator needle reaches its

lowest point as the crankshaft is being slowly rotated, it should read zero. If it doesn't, zero it yourself by rotating the ring on the dial face.

crankshaft's center bolt and have an assistant slowly rotate the crankshaft in its normal direction of rotation (clockwise as you look at its front) while you feel the rocker arm move up, then down.

When the rocker arm is at its lowest point, stop rotating the crankshaft and remove the rocker arm and

ball. With the rocker arm out of the way, secure a dial indicator stand to the engine. Then position the stem of a 0-1in dial indicator squarely into the lubrication hole in the end of the pushrod. Push the indicator stem down onto the pushrod so that it rotates about one revolution (0.100in). This is called "preloading the indica-

tor" and is essential to achieving an accurate measurement.

Now rotate the ring on the perimeter of the dial face so that the indicator needle points to zero. While keeping a careful watch on the indicator needle, have your assistant slowly rotate the crankshaft in the normal direction of engine rotation. As the crankshaft is rotated, the indicator needle will reach a high point, then a low point. When the needle is at its lowest point, it should read zero. If it doesn't, rotate the ring on the dial face until the needle points to zero. This zeroing of the indicator will help ensure an accurate lift reading.

Again have your assistant slowly rotate the crankshaft in the direction of engine rotation while you watch the indicator needle. The highest needle reading equals maximum lobe lift.

If lobe lift is more than 0.002in below specifications, the lobe is excessively worn—and the camshaft and all the lifters must be replaced. Don't try to save money by using your old lifters because they'll ruin a new camshaft in just minutes.

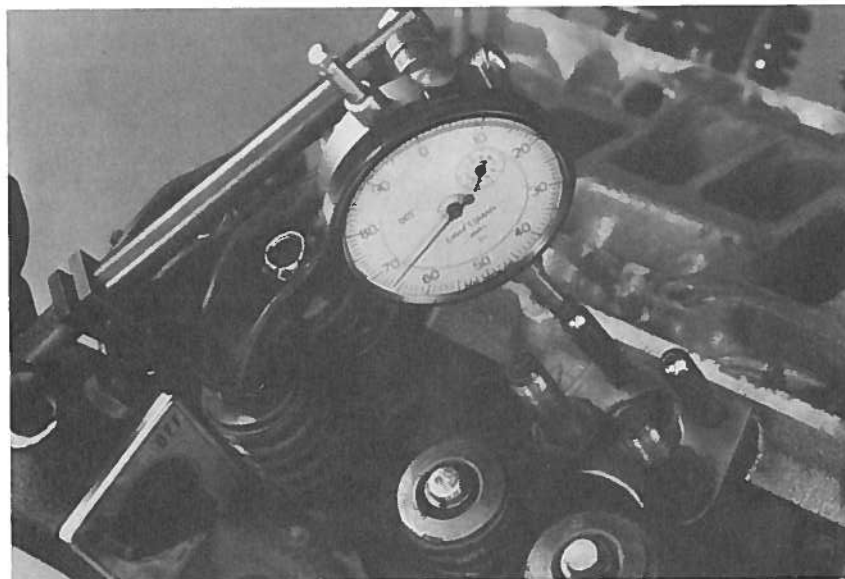
To replace the camshaft in a front-wheel-drive car or a Fiero, you'll at least have to raise the engine far enough to remove and install the camshaft. Those of you with rear-wheel-drive vehicles have it easier in that, in many cases, you'll only have to remove the radiator to remove and install a camshaft.

Compression Testing

Compression testing is an important process. It can help you assess the condition of your engine, as well as provide information about what's wrong with your engine, and the general location of the problem.

An engine's ability to compress air is essential to its making power. A compression test ensures that the engine is compressing air as it should by testing the sealing properties of the components that are designed to seal air in. This includes the piston, piston rings, intake and exhaust valves, cylinder head, and cylinder head gasket.

Two types of compression testers are available. One has a rubber nozzle that you hold against the spark plug hole in the cylinder, the other has a threaded fitting that screws into the spark plug hole. Since modern engine compartments are cramped and more than 100lb of com-



Pay careful attention to the indicator needle as the reading rises. The high-

est needle reading indicates maximum lift.

pression force is common, the rubber nozzle version can be difficult to hold in position. A screw-in tester is well worth the extra money as it will be both more accurate and easier to use.

To ensure that the compression test is as accurate as possible, certain conditions should be met. The engine should be warm (but not hot), the throttle held wide open, the battery fully charged, and all spark plugs removed. A fully-charged battery ensures that the engine will crank at the same rpm as you test each cylinder. Holding the throttle open and removing all the spark plugs allows the engine to crank at an rpm sufficiently high to ensure accurate results. However, before you remove the spark plugs, just loosen them and then crank the engine for a few seconds to blow out any dirt and grime that may have accumulated around the plugs.

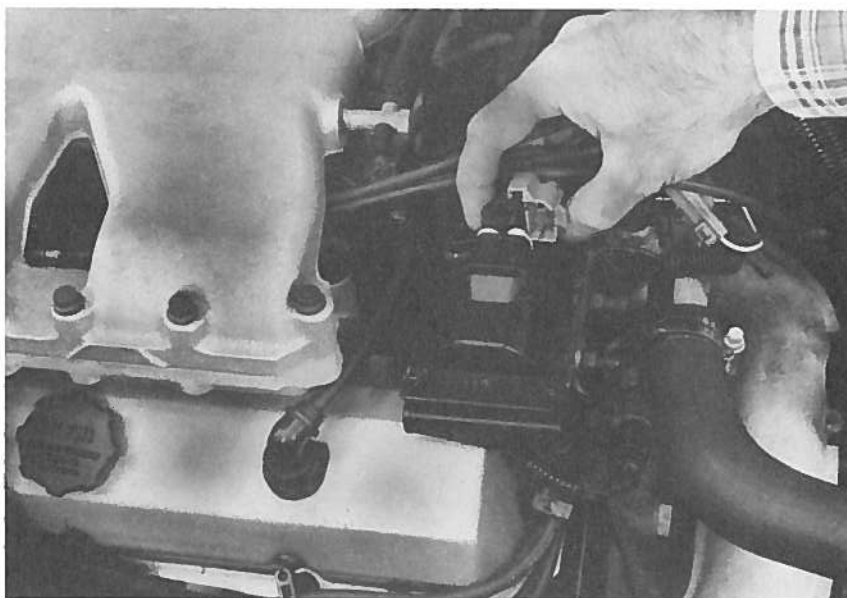
To prevent unnecessary strain on the ignition system, disable it by disconnecting all the wiring harnesses from the ignition coil or module. Refer to the accompanying photos for details. After the ignition system is disabled, screw the compression tester into the spark plug hole for cylinder #1 (see the accompanying illustration for this location). Press in the relief valve on the back of the gauge to release any residual pressure, and make sure the needle points to zero.

Now have your assistant crank the engine while you watch the gauge needle. If the engine is in good shape, the reading should rise on each compression stroke. Under normal conditions, you'll need four to six compression strokes to achieve full pressure in each cylinder.

If the sealing properties of the rings, valves, and cylinder head gasket are good, compression will build up quickly and evenly to specifications. If the piston rings are leaking, compression will be low on the first stroke and slowly build on the following strokes, but it won't reach specifications. If the valves are leaking, compression will be low on the first stroke, but it won't build up on the following strokes.

Wet Compression Testing

If the reading for any cylinder is below normal, you'll need to perform a wet compression test. Simply remove the compression tester, and, using a pump-type oil can filled with clean motor oil, put three squirts of oil into



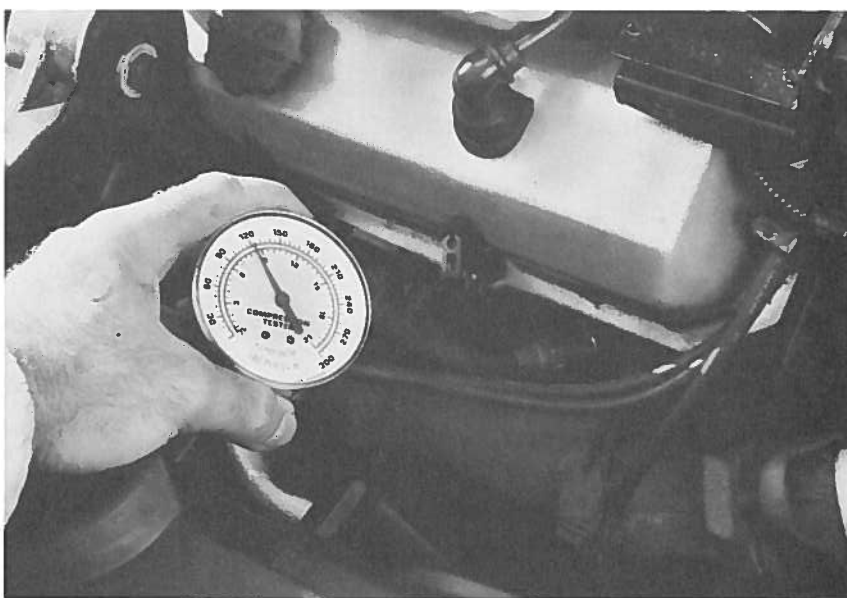
Disconnect the wiring harnesses from the ignition coil to disable the ignition system.

the cylinder through the spark plug hole. Install the tester, and run the test again.

If the pressure reading rises by 10psi or more compared to the first test, chances are good that the piston rings are leaking. The oil helped seal the piston rings well enough to increase the pressure in the cylinder. If

the compression reading is unchanged, the valves are leaking or the cylinder head gasket is blown.

Before you remove the cylinder heads to repair leaking valves, first make sure that they're not being held open by the rocker arms. Do this by removing the rocker arm covers and checking that you can move the



The highest compression reading will occur after four to six compression strokes.



If compression is low, make sure the rocker arms for the cylinder in question

aren't holding the valves open. If they are, adjust them.

rocker arms side-to-side slightly when the cylinder is at the top of the compression stroke. If you can't move the rocker arms on the "low" cylinder, they're holding the valves open. This will allow cylinder pressure to bleed off past the valves. Refer to Chapter 6 for the valve lash procedure, then run the compression test again.

When you've tested all the cylinders, compare their readings. No

cylinder reading should be less than 75% of the highest cylinder reading. For example, if the highest cylinder reading is 160psi, none of the other cylinders should be less than 120psi ($160 \times 0.75 = 120$). The less variance among cylinders, the better.

If two adjacent cylinders each have similar pressure readings that are significantly below the other readings, then the cylinder head gasket

between those cylinders is probably leaking or blown. When a cylinder head gasket fails like this, the pressure from one cylinder bleeds off into the other, which more or less equalizes the pressure between the two cylinders and lowers it below that of the other cylinders.

Dynamic Compression Testing

Dynamic compression testing can help you decide whether a valve-train problem is causing an intermittent miss at idle.

To run a dynamic compression test, all the spark plugs except for the cylinder you're testing should be in place and operational. Screw the compression tester into the cylinder in question. Start the engine and run it at idle. To prevent an erroneous compression reading, bleed off any residual compression by pushing in the tester's pressure release valve. As the engine idles, record the reading on the gauge. Perform this test on all remaining cylinders, always using the same idling speed.

After you've tested all the cylinders, compare their readings. If any cylinder has a reading that's 15% or more below the others', the valves aren't sealing properly. This is usually due to a problem with the valves or in the valvetrain, such as improper adjustment. And don't get depressed if compression is 50–75% below a cranking compression test, because that's normal.

Leakdown Testing

Leakdown testing is quite similar to compression testing, indicating the condition of the piston rings, intake and exhaust valves, and cylinder head gasket. Leakdown testing is more accurate than compression testing, however, because you don't have to factor in engine cranking speed, valve duration, or altitude.

A leakdown tester consists of two gauges joined by a block of aluminum or steel. One end of a short length of air hose is screwed into one end of the block and the other end is screwed into the spark plug hole of the cylinder to be tested. An air line from an air compressor is attached to the other end of the block.

Air from the air compressor runs to the first gauge, which regulates air pressure going into the cylinder. The other gauge measures the



When leakdown testing, the cylinder being tested must be at top dead center (note, the timing mark on the

damper is at zero) on the compression stroke.

amount of air pressure that the cylinder is holding. The difference between these two air pressures represents the leakdown percentage

The first gauge is usually set to 100psi so that it is easier to determine the leakdown percentage. For example, if the first gauge is at 100psi and the second gauge reads 90psi, the cylinder has a leakage rate of 10% ($100-90=10$).

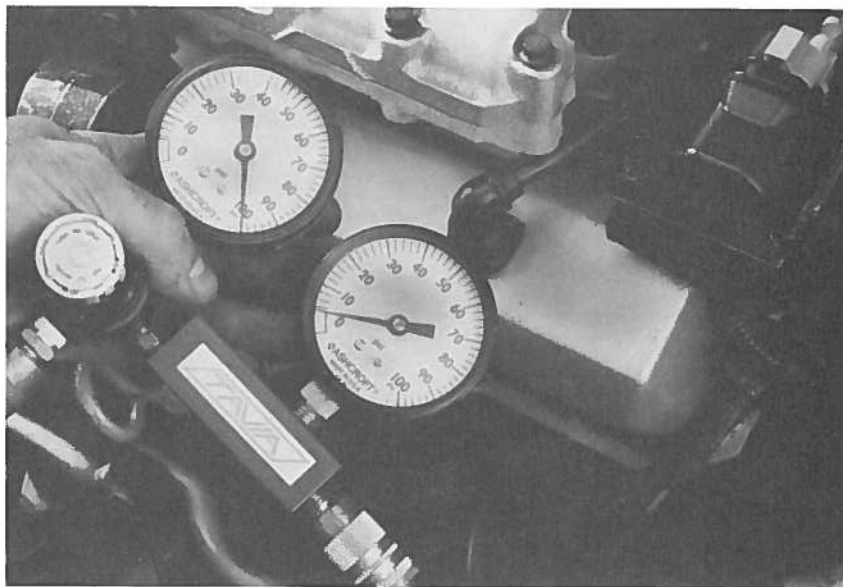
It's important that the piston for the cylinder being tested be at top dead center (TDC) on the compression stroke, otherwise the crankshaft may rotate instantly when the cylinder is pressurized. To ensure the piston is at TDC, remove the rocker arm covers and watch the intake valve rocker arm for cylinder #1 as the crankshaft is rotated. When the valve side of the rocker arm reaches its highest point and the timing mark on the harmonic damper at the front of the engine is at TDC, you should be set to leak test cylinder #1. To verify that the piston is at TDC, carefully insert a long, thin screwdriver through the spark plug hole until it gently contacts the top of the piston. Have someone slowly rotate the crankshaft back and forth slightly. Touching the screwdriver, you should be able to feel the piston move up, stop, then move down. When the piston stops at the top of its stroke, it's at TDC.

To help keep the engine from turning over during testing in vehicles with manual transmissions, put the transmission in first gear and apply the parking brake. If your vehicle has an automatic, have your assistant hold the crankshaft damper bolt with a long breaker bar while you test. Be sure to clear anything that could cause injury if the crankshaft were to suddenly turn.

After testing cylinder #1, test the rest of the cylinders following the firing order (1-2-3-4-5-6). Then calculate the leakdown rate for each cylinder.

A leakdown rate of 10% or less means that the cylinder is sealing well. If the leakdown rate is 10-20%, cylinder sealing is acceptable, but if it's greater than 20%, you have a cylinder sealing problem.

To determine which component is causing the problem, use your senses of touch and hearing. If you feel and hear air coming out of the exhaust, the exhaust valve is leaking. Conversely, if you feel and hear air coming out through the carburetor or



A leakdown tester is the best way to check the internal condition of an engine. To use the tester, you'll need a source of compressed air. Watch both gauges carefully and record your read-

ings. This will make it easier to identify problem cylinders. This cylinder is sealing very well, as evidenced by its leakage rate of only 2-3%!

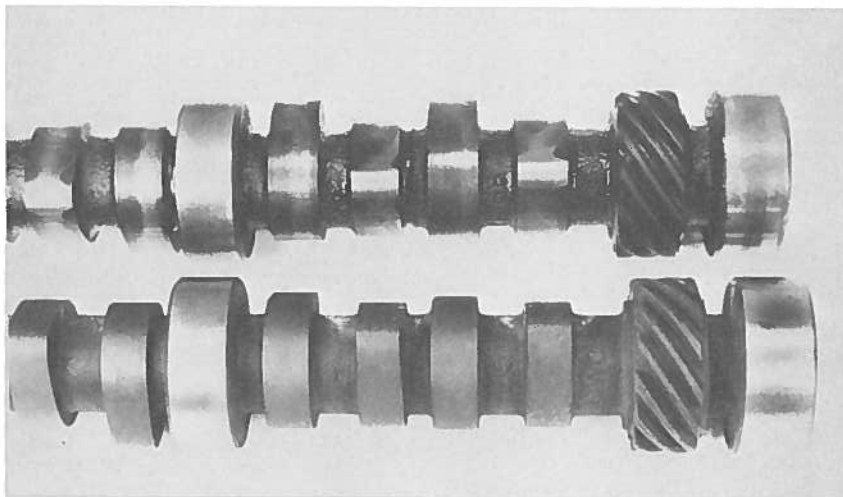
throttle body (when the throttle is open), then the intake valve has a sealing problem. And if you feel and hear air coming out the engine dipstick tube (with the dipstick removed), the piston rings aren't sealing well.

As with dry compression testing, when you've finished testing all the cylinders, compare their readings. If the readings for two adjacent cylinders are significantly below those of the other cylinders, the cylinder head

gasket between those two cylinders is blown.

Testing Conclusions

With your tests and checks complete, you can now determine if the engine should be rebuilt. If your diagnosis indicates that the engine has reduced power, but oil pressure is acceptable, oil consumption isn't bad, and no strange sounds are coming from the engine, you can probably coax some more miles out of it. If your



Worn cam lobes can cause an engine to be down on power. The lobes on the

upper camshaft have seen better days. The lower camshaft is new.

testing reveals that the cam lobes are wiped out, but the rest of the engine is in good shape, simply replace the camshaft, lifters, and timing chain. An engine rebuild isn't necessary. However, if the engine has low oil pressure, engine-based knocking or rapping noises, or metallic particles in the oil, it needs to be rebuilt.

Economics of Rebuilding Budgetary Considerations

Now that you know a rebuild is necessary, you need to budget money

for all the parts and services. You need to consider several things when setting a budget. How much money do you have to spend? Are you going to buy only the parts you absolutely need, or are you leaning toward a complete engine rebuilding kit?

Consider this: A complete, high-quality gasket set for the GM 60deg V-6 costs about \$80 at an auto parts store. Quality connecting rod and main bearings cost another \$70 and piston rings cost about \$60 for a set. These parts are the bare minimum

you'll need—and they total \$210.

On the other hand, a complete, high-quality engine rebuilding kit, which typically includes a set of pistons, piston rings, camshaft, lifters, connecting rod bearings, main bearings, timing chain, timing gears, oil pump, and complete gasket set, costs \$450–\$500 if purchased locally, or \$400 by mail.

Selection of parts can't be based on costs alone, however. Your supplier is critical as well. If the parts you receive aren't the right type or size, will the supplier exchange them or give you your money back? If you need to exchange parts, how long will it take to get them (a scheduling consideration)? When a supplier asks you for the size of a particular component, such as bearings, how will you know what size you need if you haven't torn down the engine to see how much wear is on the crankshaft? And if you have the engine torn down, will you be waiting for parts with nothing to do? Consider all these factors before selecting your supplier.

Machine shop expense should also be included in your budget if you plan on having the valves and valve seats ground, heads or cylinder block milled or hot-tanked, the crankshaft ground, or the block bored and honed for larger pistons. These things are often necessary, or at least desirable, because they result in a better, longer-lasting engine, but they add to your costs as well.

Commercially Rebuilt Engines

A company in your area may supply rebuilt engines for nearly what it would cost you to do it yourself when you factor in the cost of parts, machine shop work, and tool rental. This may be the way to go, especially if you lack time or experience, but do some careful checking before you buy. Just because an engine is offered at a reasonable price doesn't mean it's been properly or carefully rebuilt.

Qualify the shop by asking questions: Are the shop's technicians adequately trained to rebuild engines? Both National Institute for Automotive Service Excellence (ASE) certification or state certification are reliable indicators of knowledge. Is the company affiliated with a national organization that promotes excellence and fairness, such as the Automotive Engine Rebuilders Association? Does the company use quality automotive

Symptoms

The following information summarizes the detailed checks covered in this chapter and will help you locate the cause of a poor performance problem.

Lopes at Idle or Idles Roughly

- PCV valve plugged
- PCV hose restricted
- EGR valve leaking
- Engine overheated
- Inlet manifold to cylinder head seal leaking
- Camshaft lobes worn
- Cylinder head gasket leaking or blown

Lack of Power

- Clutch slipping
- Brakes dragging
- Regulator valve in automatic transmission sticking
- Fuel octane below requirements
- Engine overheated
- Knock sensor failed
- Check engine or Service Engine Soon(or SES) light on
- Spark plug gap incorrect
- Spark plugs dirty
- Ignition timing incorrect
- Valves improperly adjusted
- Fuel mixture too rich or too lean
- Fuel injectors plugged
- Exhaust system (usually the catalytic converter) restricted
- Carburetor float level incorrect
- Distributor advance weights sticking
- Ignition coil weak
- Fuel pump faulty
- Valve timing incorrect (slipped timing chain)
- Valve springs weak
- Valves sticking
- Camshaft lobes worn
- Cylinder compression low
- Cylinder head gasket leaking or blown

Stalls

- Exhaust system (usually the catalytic converter) restricted

- Engine overheated
- Fuel contaminated with dirt or water
- Spark plug gap incorrect
- Spark plugs damp or fouled
- Fuel injectors restricted or plugged
- Carburetor needle valve sticking
- Carburetor flooding engine with fuel
- Carburetor float level incorrect
- Carburetor choke incorrectly adjusted
- Carburetor choke sticking
- Carburetor mounting gasket leaking
- Inlet manifold gasket leaking
- EGR valve leaking
- Distributor advance weights sticking
- Ignition coil faulty
- Valve adjustment incorrect
- Valves sticking, warped, or burned
- Cylinder compression low

Misses at Idle

- Carburetor idle adjustment incorrect
- Spark plugs wet or gap incorrectly set
- Spark plug wires wet
- Spark plug wires insecurely attached
- Distributor cap wet inside
- Distributor cap cracked
- Ignition coil faulty
- Fuel contaminated with water or dirt
- Distributor advance weights sticking
- EGR valve leaking
- Valve adjustment incorrect
- Cylinder compression uneven or low

Misses at Various Engine Speeds

- Distributor cap or rotor carbon-tracked
- Ignition timing incorrect
- Engine overheated
- Spark plug gap too wide
- Fuel pump faulty
- Carburetor jets restricted
- Ignition coil weak
- Fuel contaminated with water or dirt
- EGR valve leaking
- Distributor ignition point cam worn
- Valve springs weak
- Camshaft lobes worn
- Electronic control module (ECM) ground connection bad at thermostat and/or block

parts, such as TRW, SpeedPro, Cle-vite, and FelPro? Does the company do the machining in-house or send it out? Is the machining equipment in good condition and operated by skilled machinists? One clue that the shop is reputable is its cleanliness. If the interior of the shop looks dark and dingy, chances are you should pass it up. Sloppy machinists have sloppy habits.

You also need to know whether a warranty is offered with the engine. The longer the warranty, the better. Get a minimum of one year or 12,000 miles. Some shops offer an extended warranty for an additional fee. You also need to know what the standard (and extended) warranty covers. If the shop has really done its work well, it should cover all engine components, seals, and gaskets. Finally, you need to find out whether the warranty is valid if you install the engine yourself.

The one item all this business of buying a rebuilt engine doesn't address is the satisfaction you'll receive knowing that you rebuilt your engine yourself. The feeling you get from hearing the engine you meticulously reconditioned roar to life for the first time is hard to equal. An added benefit of doing the work yourself is that you know exactly what parts were used and how they were installed. This can give you peace of mind like no rebuilt engine could.

Time Requirements

Now you may have read about or heard about someone who rebuilt his engine over a weekend—and it's still running years later. If this is true, his name must be Smokey Yunick, one of stock car racing's most prominent technical wizards. The rest of us need significantly more time than this.

Realistically speaking, if this is your first engine rebuild, and you're mechanically inclined, set aside eighty hours or so to do a thorough job. This will allow time for cleaning all the engine components, inspection, measuring, machine shop work, and engine assembly. This figure doesn't include any time for removing or installing the engine. Depending upon the vehicle housing the engine, your level of motivation, and how your luck falls, this could take anywhere from sixteen to forty hours. So, plan on about 100 hours total if this is your first engine rebuild.



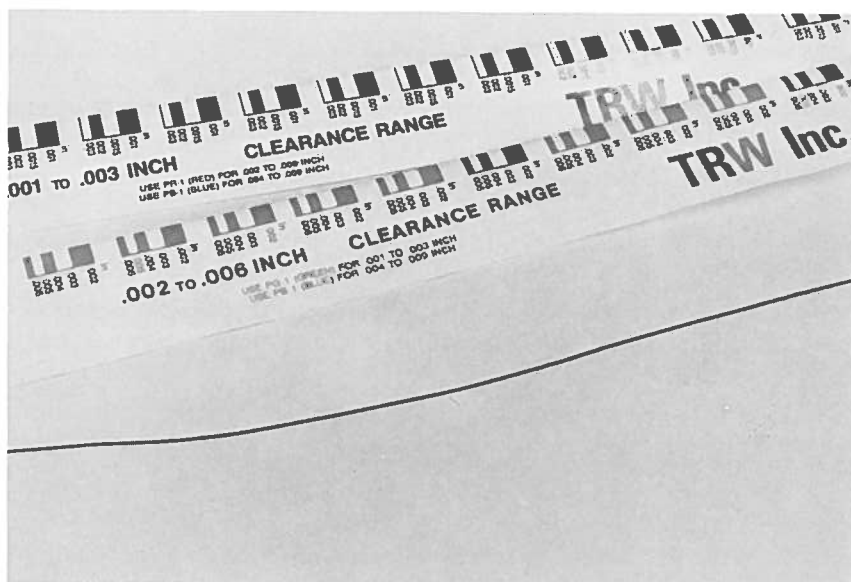
A band-type ring compressor will do the job for most amateur engine rebuilders. A screwdriver can be used in lieu of an

extension bar to tighten the ratchet mechanism.

Work Area

Your work area is another consideration, as it can have a bearing on both the quality of your rebuild work and your sanity. Do you have a garage to work in, or will you be working on the engine outside? If you're working

outside, you'll need to take extra care and time to keep the engine clean during assembly. If you have a garage, is there room enough to work around the vehicle? Does that include room for an engine hoist and stand? Will somebody's car have to be taken



Plastigage is the poor man's way of checking bearing clearances. This material looks like a thick hair before it's

compressed. Although three thickness ranges are available, you'll need only the 0.001-0.003in size.

out of the garage before you can begin work? Will that person be accommodating if your work schedule slips a bit because of other obligations?

Tools

Aside from the "normal" complement of tools, such as assorted box- and open-end wrench-es, sockets, screwdrivers, pliers, hammer, feeler gauges, and gasket scraper, very few special tools are needed to rebuild the GM 60deg V-6 engine. Just remember that all the fasteners both outside and inside the engine are metric. One metric tool that you'll need, but usually don't find in a tool set, is an 18mm socket, which fits the bell housing bolts, among others.

A torque wrench is essential to putting the proper load on bolts. A simple beam-type torque wrench costs about \$20 and is worth every penny. A 1/2in drive version with a range of 140lb-ft should handle your needs. These are available at many better auto stores and some large retailers such as Sears.

A piston ring compressor is another tool that you'll want. This tool makes the installation of the piston assembly possible.

Connecting rod and main bearing clearance can be checked fairly accurately with gauging plastic. Gauging plastic (known in the trade as Plastigage) is a specially formulated plastic that compresses at a controlled rate. Once it's compressed, you compare its width with the markings on its storage envelope to determine bearing clearance. Gauging plastic is inexpensive and is available at most auto parts stores.

Dial indicators, micrometers, and snap gauges are serious tools that offer the utmost in accuracy if you know how to use them. However, they're something of a luxury if you're going to rebuild just one engine. All of the critical measurements, such as measuring the crankshaft journals and checking the cylinder heads for warpage, can be performed at a machine shop. If you want or need these types of tools, rent them.

You'll need an engine hoist to remove the engine. You can rent one from a local tool rental company for \$15 to \$20 a day. Be sure to get the lift chain as well.

An engine stand isn't necessary, but it is a handy tool to have because it puts the engine at a normal work-

ing height and lets you rotate the engine 360deg. This gives your back a break and makes removing and installing the crankshaft, pistons, and connecting rods much easier than if the engine was on the ground. The engine also stays cleaner.

You can rent an engine stand, but if you're going to have it for more than a few days, you're better off buying one. The \$60 or so you'll spend will be well worth it, especially if you plan on rebuilding other engines.

Factory Service Bulletins

Since the 60deg V-6 was introduced, it has gone through many changes. Sometimes these changes were made to address a problem that occurred as these engines accumulated real-world miles. Not all of these changes could be tracked here, so I strongly advise that you get all the factory service bulletins that apply to your particular engine and vehicle combination. Per a Federal Trade Commission ruling, these service bulletins are available at no charge at your local GM dealership.